A600 v2.1 1.8-72MHz 600W amplifier kit

I designed, built and tested this in my spare time with little expectations, a lot of curiosity and a hope to make my small contribution to the Amateur Radio world. I trust you will enjoy putting this together and using it in the spirit of Amateur Radio.

If you have any issues, I'm just an email away.

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The A600 v2.1 is a 600W 1.8MHz to 72MHz linear amplifier that uses low-cost but latest-technology LDMOS RF transistors. It includes some improvements over the previous version (v2.0) and is designed to make it easier to assemble and use. This is an Advanced level kit and assumes you have a good understanding of electronics.

To assemble this kit you will need the following tools & materials:

- soldering kit
- multimeter with a current range over 1A
- utility knife
- a short piece of RG-213 or similar coaxial cable
- electrical tape
- Tools to drill, tap or further machine aluminium and / or copper (as needed)
- M3 & M4 bolts (or equivalent) to attach the board and power devices to the heatsink

To be able to test and then use the A600 on the air, you will need the following:

- a large heatsink to install the module on (0.1C/W is sufficient for normal use)
- a solid 48V/25A power supply
- a low pass filter for each band you plan to use this on
- circuitry that will switch the amplifier in/out of the circuit
- conductors, connectors as needed
- additional monitoring and protection circuitry is recommended.

Sensor Port

The Sensor Port (J5) is designed to interface with microcontrollers for measurement and control. Outputs are generally high impedance so it's recommended to use buffers (unitary gain opamps for example) if you want to drive any other types of circuitry than ADC inputs. It is highly recommended to use a ferrite choke on the cable that connects to J5 and decouple each signal with a 10nF ceramic capacitor to ground at the other end.

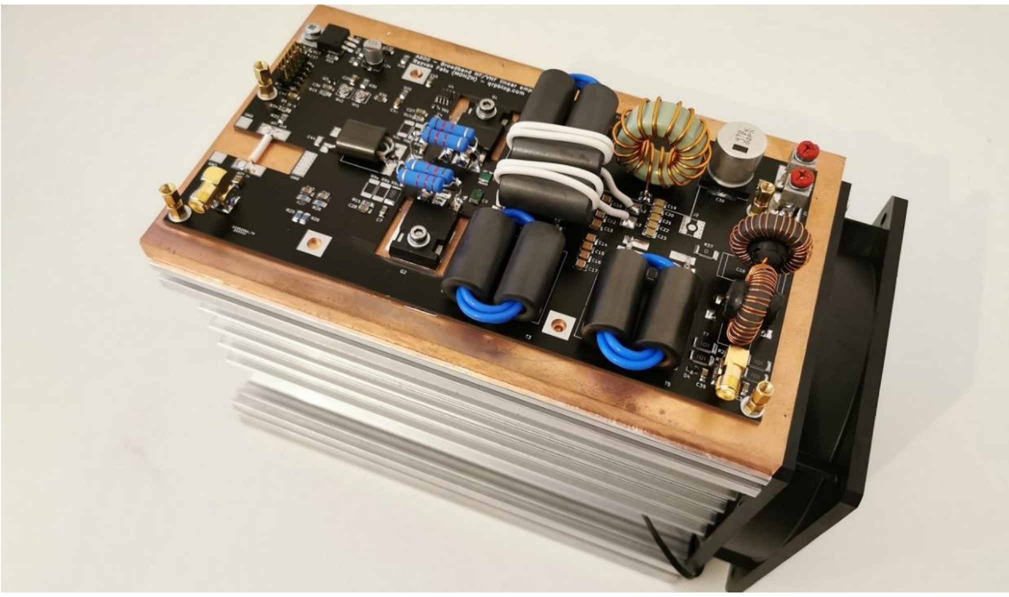
Pin	Name	Description
1	GND	Reference ground for measurements.
2	Vsense (output)	Voltage directly proportional to the PA Unit supply voltage, increases with approx. 0.0485V for every 1V at the supply. For 48V this pin should provide about 2.33V output.
3	GND	Supply ground
4	Isense (output)	Voltage directly proportional to the PA Unit current draw. For zero current this pin sits around 0.5V and it increases with 0.133V for every 1A drained from the supply. See the ACS713ELCTR-30A datasheet for more information.
5	+5V	+5.36V supply output, max 200mA combined with pin 7
6	Vtemp (output)	Voltage directly proportional to the heatsink temperature. This output increases with 0.01V for every 1 Celsius degree. Expect 0.20 to 0.30V output for normal room temperature and 0.50V for the recommended thermal limit. See LM35D datasheet for more information.
7	+5V	+5.36V supply output, max 200mA combined with pin 5
8	REFsense (output)	Voltage proportional to the amplifier output reflected power square root. Around 3.20V for 600W.
9	BiasDisable (input)	Apply a positive voltage to this pin to reduce the power transistors' bias voltage. Around 1V should be enough to cancel the idle current completely; don't exceed 5V.
10	FWDsense (output)	Voltage proportional to the amplifier output forward power square root. Around 3.20V for 600W.
11	GND	Supply ground
12	Vdrive (output)	Voltage proportional to the input drive power square root. 1.6V for 5W.

Heatsink & cooling

For optimal cooling in normal conditions, the amplifier requires a heatsink that achieves around 0.1C/W thermal resistance. There are formulas that allow you to calculate the performance of a heatsink based on surface and air speed, but if the manufacturer doesn't provide that information it's best to follow the principle "bigger is better". If not sure, monitor the temperature pin output from the sensor port during tests to make sure this never goes above 50C.

A copper heat spreader can be “sandwiched” between the power amplifier and the aluminium heatsink to provide a better path for heat; this will also allow you to use liquid metal Thermal Interface Material (such as Thermal Grizzly Conductonaut or Coollaboratory Liquid Metal Pro) for best thermal transfer and electrical contact. This might raise some challenges but is the best thermal solution.

To drill copper and aluminium I recommend using good quality HSS drill bits, plenty of cutting fluid and a low drilling speed; this will avoid having drill bits stuck / broken.



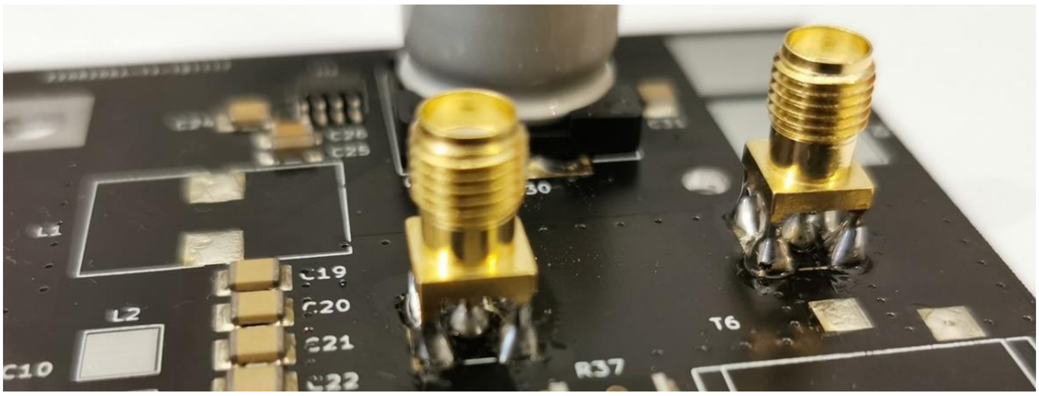
Example of A600 amplifier module installed on a heatsink

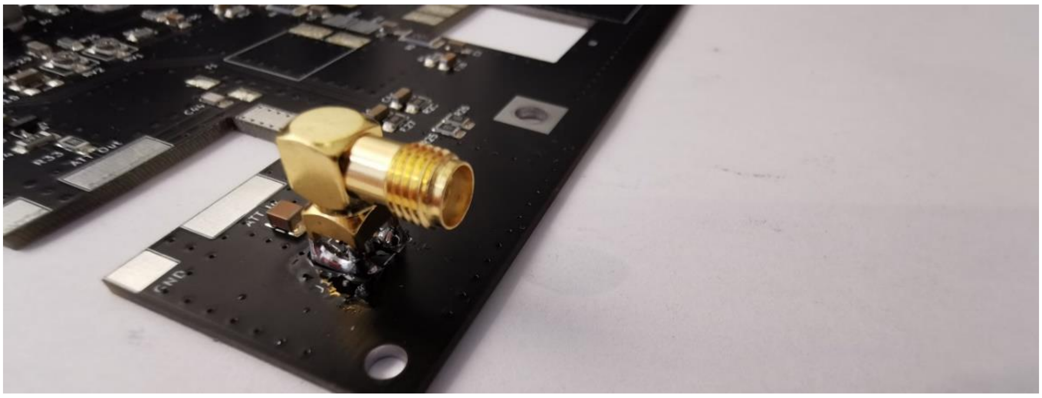
Bill Of Materials

Reference	Description	Value	Package	Code
PCB	Printed Circuit Board		190*100mm	v2.1
R31a	Resistor	1200 / 3W	THT	ROX3SJ1K2
R31b	Resistor	1200 / 3W	THT	ROX3SJ1K2
R32a	Resistor	1200 / 3W	THT	ROX3SJ1K2
R32b	Resistor	1200 / 3W	THT	ROX3SJ1K2
L1	Inductor, 16 turns	22uH	toroid	
T1	RF transformer, 2:1		binocular ferrite	
T3	RF transformer		2x ferrite tube	
T4	RF transformer		2x ferrite tube	
T5	RF transformer		2x ferrite tube	
T6	RF coupler, 33:1		toroid	
T7	RF coupler, 33:1		toroid	
U2	Voltage regulator		TO-220	LM317HVT
Q1	RF power transistor		TO-247	MRF300AN
Q2	RF power transistor		TO-247	MRF300BN
J1	Connector SMA PCB		angled	
J2	Connector SMA PCB		straight	
J3	Connector SMA PCB		straight	
J4	Connector SMA PCB		angled	
SCREW CONN	Screw power connectors	2x		
TO-220 INS KIT	TO-220 Insulation kit	2x		

Install SMA connectors

There are 2 straight and 2 angled SMA connectors in the kit, you can choose which to use where for J1, J2 J3 and J4. These connectors are designed for THT mounting so they have long pins; this will allow you to solder them in place using a soldering iron with a thin tip. Solder the central pin first and after you are sure it's aligned correctly, solder the other 4 corner (ground) pins in place.



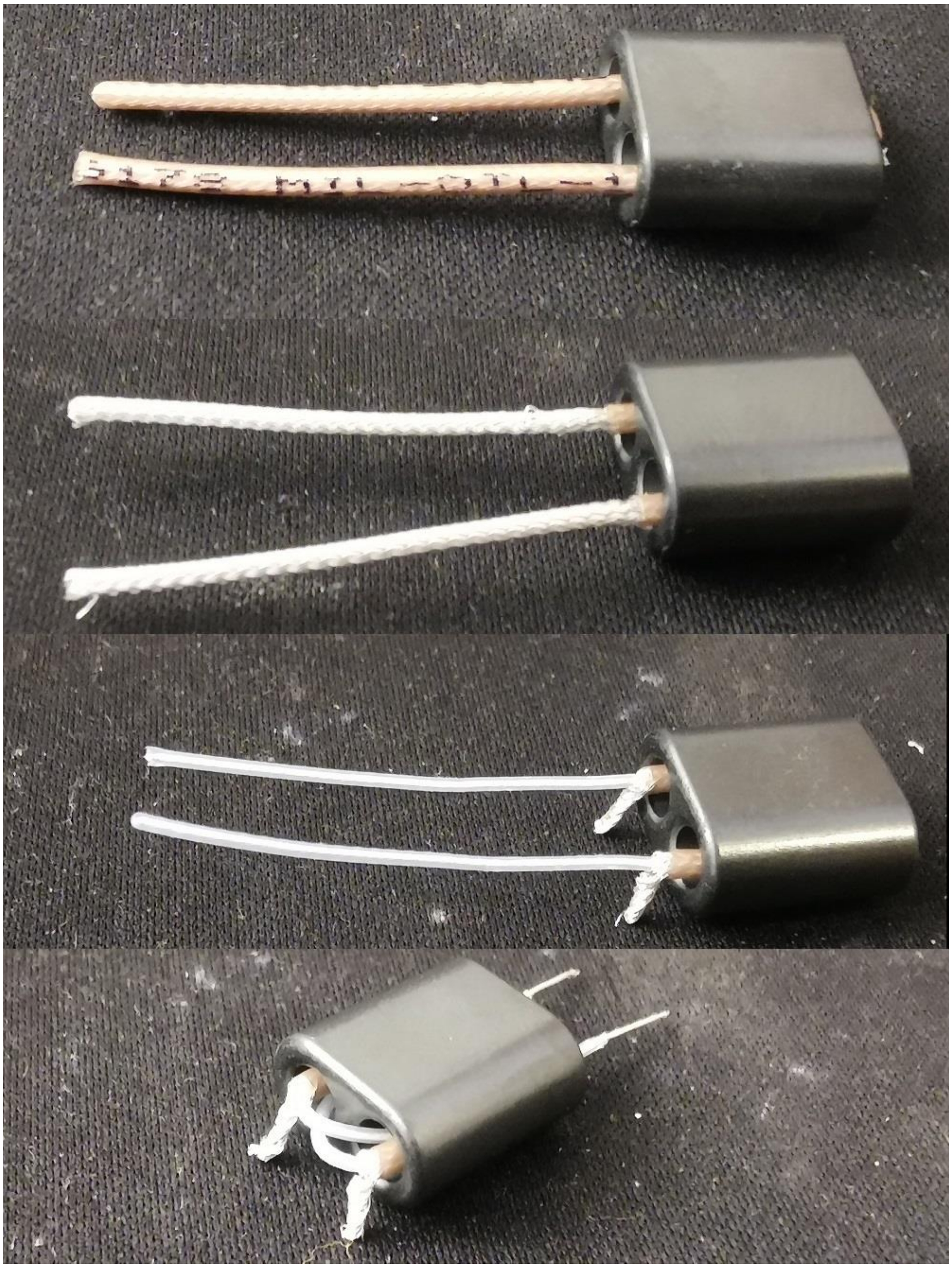


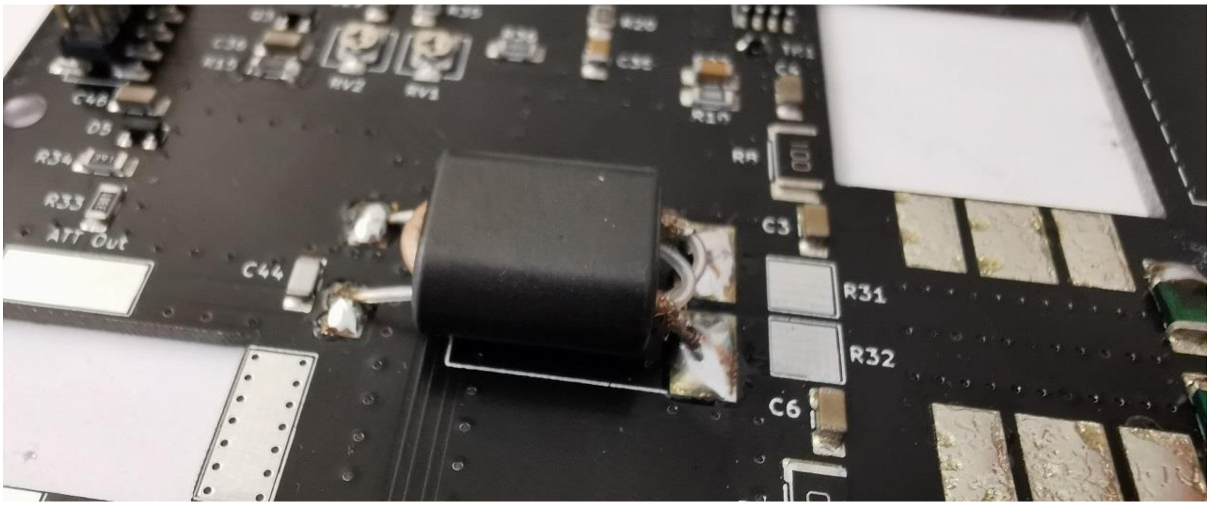
Some people have complained that SMA connectors "don't look like they could handle 600W". The manufacturer specifies them for at least 600W continuous up to 1GHz and some industrial manufacturers like Hilberling use them exclusively in their 1kW+ HF/VHF amplifiers, but if you're not comfortable with this you can solder coax cables directly to the PCB instead of using the SMA connectors.

Assemble parts

Some of the parts supplied in this kit require assembly before they can be installed.

T1 - 2:1 turns ratio transformer with coaxial cable. Wind one turn of coaxial cable through the ferrite core so both ends come out on the same side in equal lengths. With the utility knife, carefully remove the external jacket off both the ends hanging out, remove the shielding and cut most of it, leaving only ~1cm (1/4 inch) on each side. Take the two insulated center conductors and pass them through the core one more time, so they come out on the opposite side. You should end up with something like in the picture:

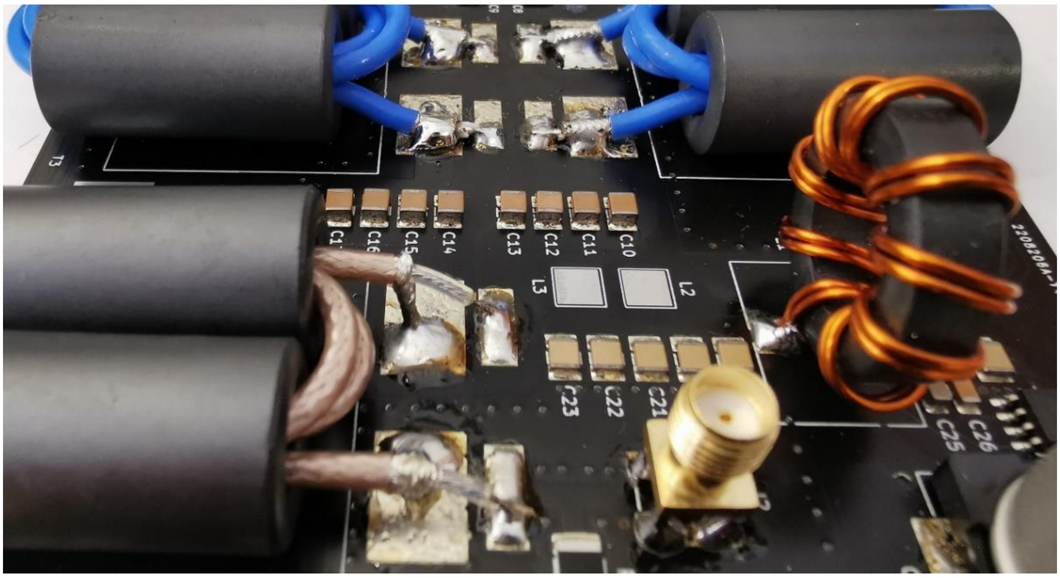




T3 & T4 - 3 turns semi-rigid line on two large ferrite cores. Carefully but tightly wind the supplied semi-rigid transmission line so it passes 3 times through each of the two cores. With the utility knife remove the outer jacket over the last 1cm (1/2 inch) at each end and then remove the shielding & insulation over the last 5mm (1/4 inch) to expose the tip of the central wire.Quicky coat in solder the exposed shielding and the central wire and then solder in place. Do not heat more than necessary as it may damage the semi-rigid line.

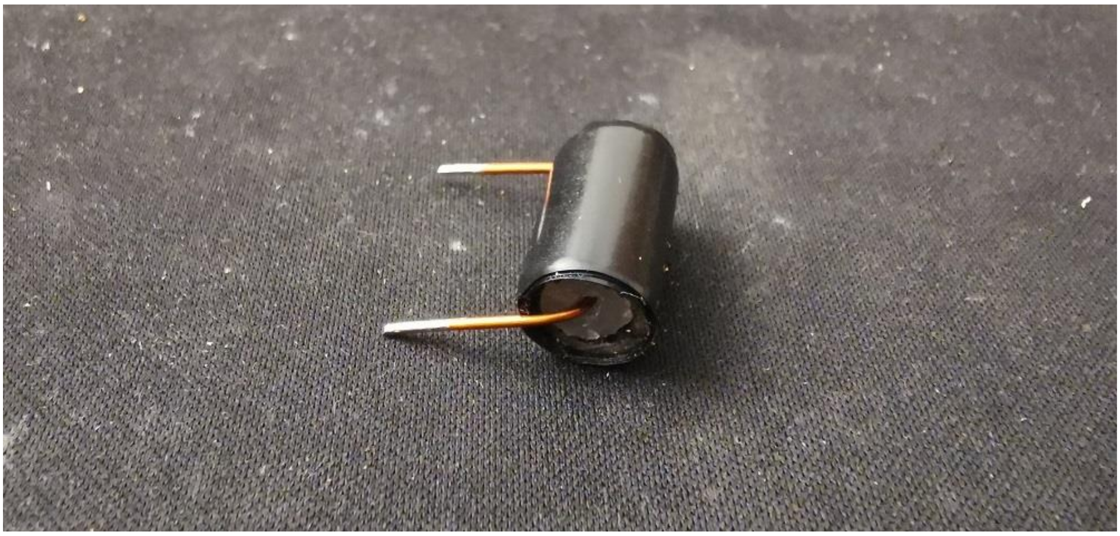
T5 - 3 turns semi-rigid line on two large core ferrites. Same as T3 & T4 (the ones on the top, blue)

Quicky coat in solder the exposed shielding and the central wire and then solder in place. Do not heat more than necessary as it may damage the semi-rigid line. Picture below for reference only (older version of the board).

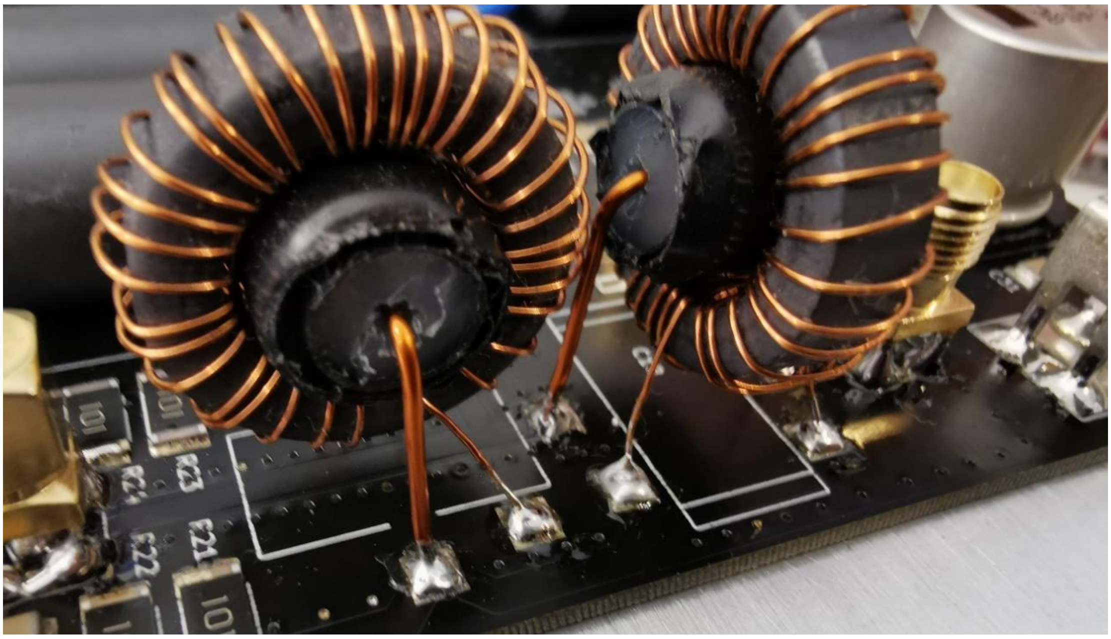


T6 & T7 - 33 turns on toroid with one central wire. Pay extra attention to symmetry with these two transformers, as it may affect forward & reflected power measurement in the higher frequencies. First, wind 33 turns of the thin wire on the toroid, as equally spaced as possible and making sure they cover about 90% of the toroid. Carefully scrape the insulation off the wire ends with the utility knife and coat in solder.

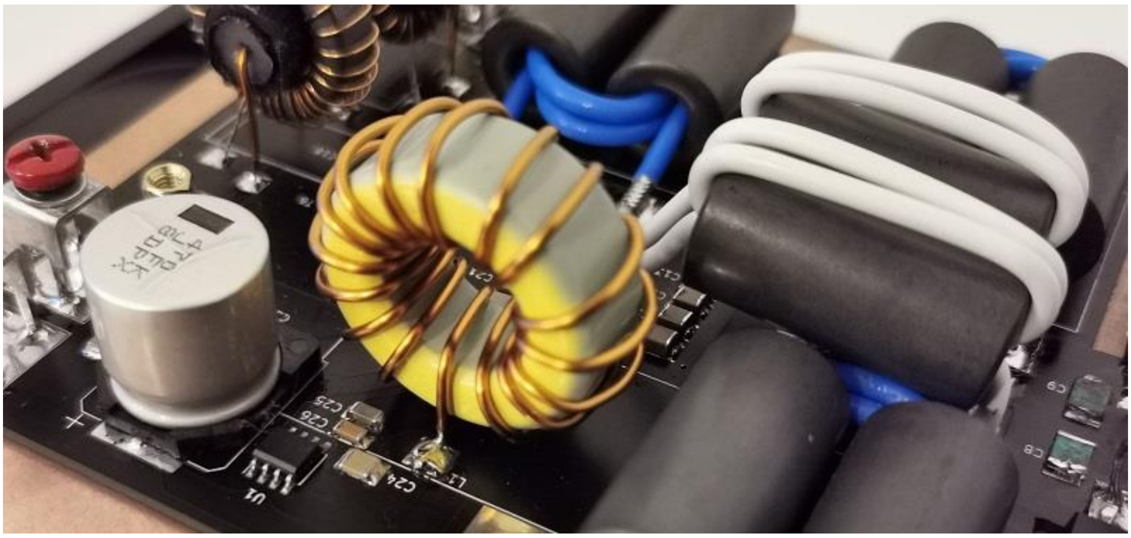
For the second step, you will need some electrical tape and small piece of RG-213 or similar coaxial cable to make the central spacer. Cut a piece of 1.5cm (around 5/8 inch) coaxial cable and remove the shielding and the central wire. Cover the central insulation with a few layers of electrical tape to make sure it's not loose inside the outer jacket. Apply a few extra layers of electrical tape on the outer jacket as well, to make sure it is a snug fit inside the toroid. Pass the thick copper wire through the central spacer, bend it at 90 degrees where it comes out, scrape the insulation off the ends and cover in solder.



Install on the board as in the picture, with sufficient spacing from the PCB.

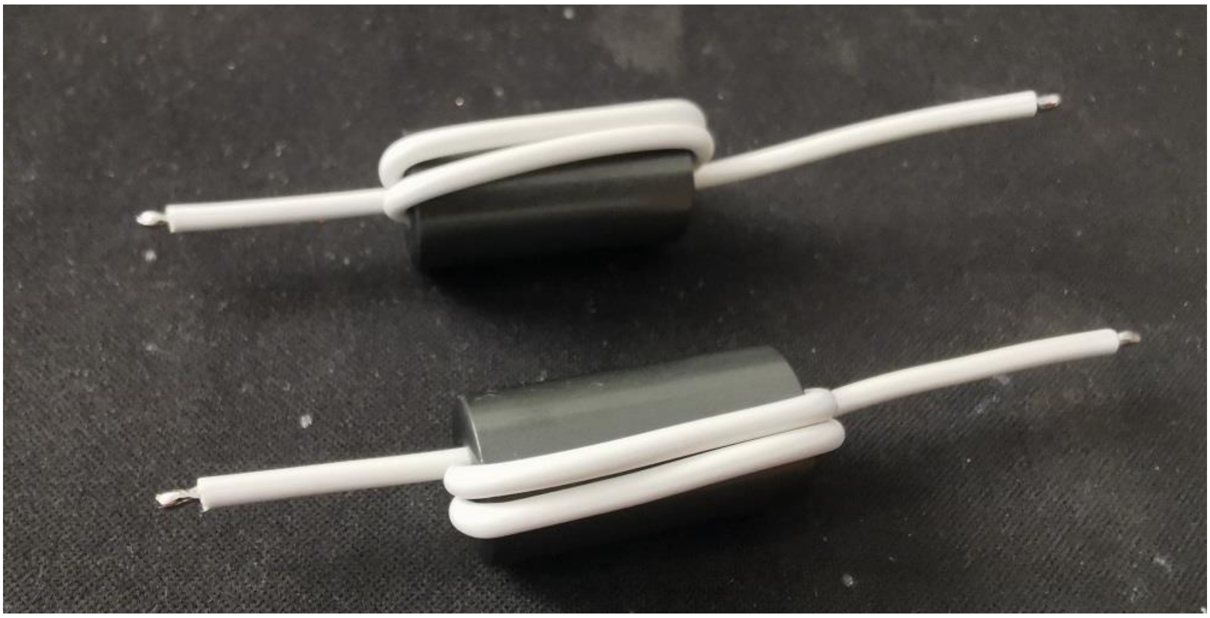


L1 - 16 turns on toroid. Wind the supplied wire on toroid; it should be enough for 16 turns, with a bit to spare. With the utility knife scrape the insulation from the wire ends.

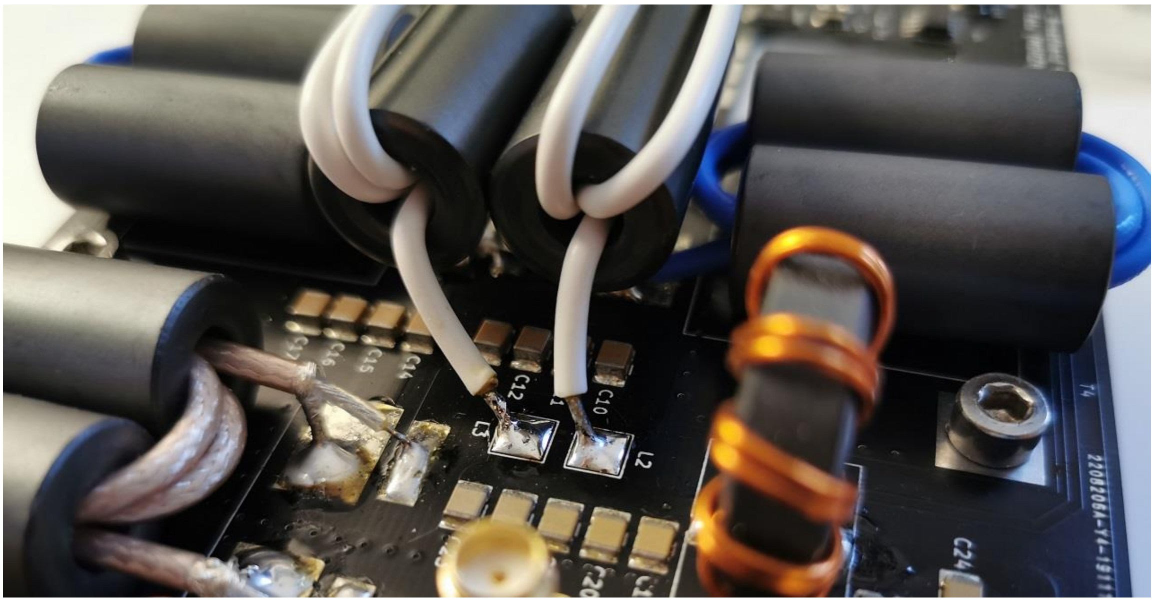


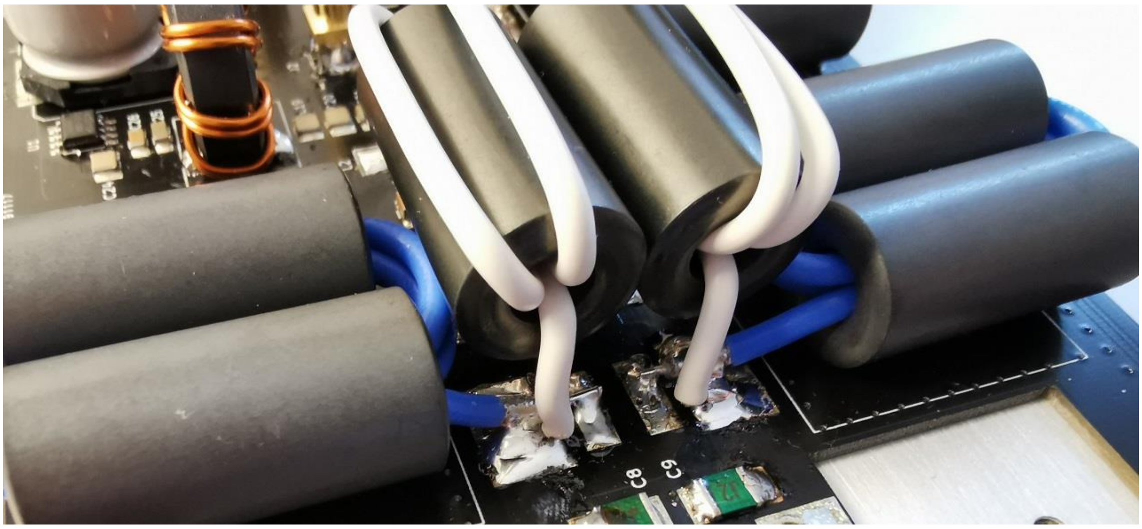
Make sure you apply a clean layer of solder coating, install L1 as in the picture and solder in place.

L2 & L3 - 3 turns on large ferrite bead. Wind the supplied wire so it passes 3 times through the ferrite core. Use the utility knife to remove about 5mm (1/4 inch) of wire jacket, coat with solder.



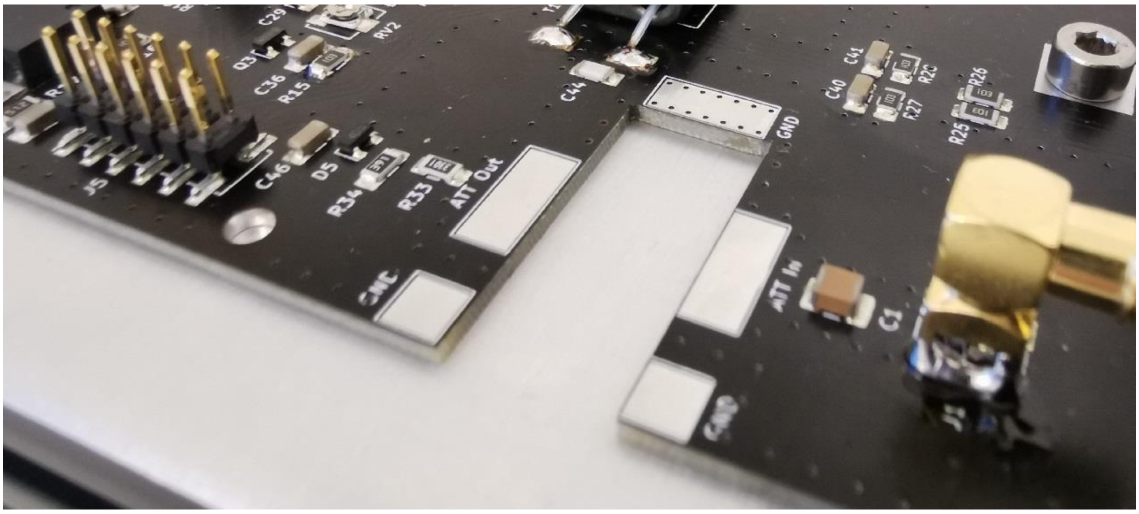
Solder in place as seen in the pictures.





Install & adjustment

If you intend to drive the amplifier with more than 5W, the PCB board has a cutout for a flanged attenuator (ATT – not supplied) as well as some exposed pads where you could build a Pi attenuator out of power resistors.



These are some recommendations for attenuators depending on your drive level:

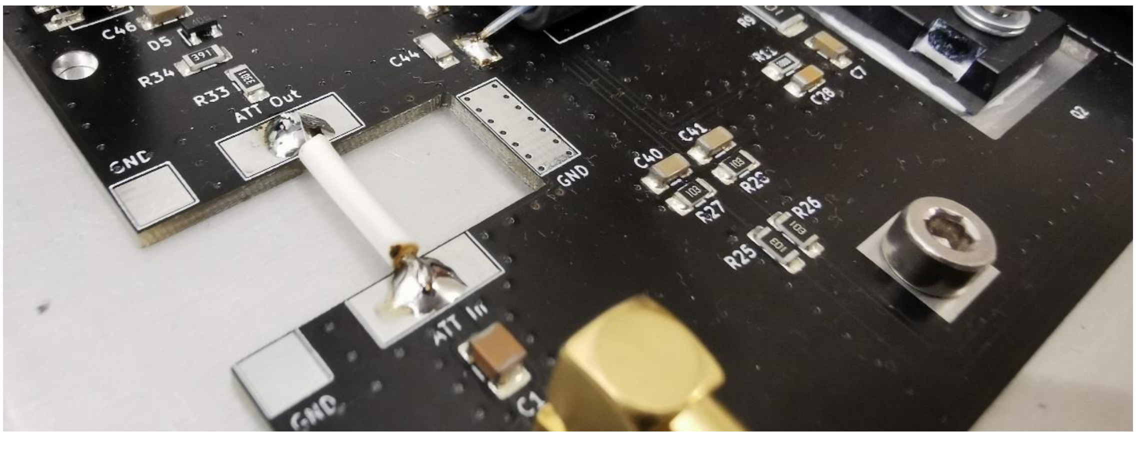
100W - 20dB attenuator: ATC FA10975P20DBFBK, Anaren RFP-100-20AE, generic RFP1398

50W - 10dB: ATC FA10975P10DBFBK, Anaren RFP-100-10AE, EMC 33A702310.00F

20W - 6dB: ATC FA10975P06DBFBK, Anaren RFP-100-06AE

10W - 3dB: Matching Pi attenuator, use 300ohm / 18ohm / 300ohm 3W carbon or ceramic / metal resistors. Do not use wire wound resistors (!).

If you have less than 5W drive or you plan to use an off-board attentuator, just install a straight wire in place of ATT. No need to worry about its inductance as the capacitor at T1's input cancels it.

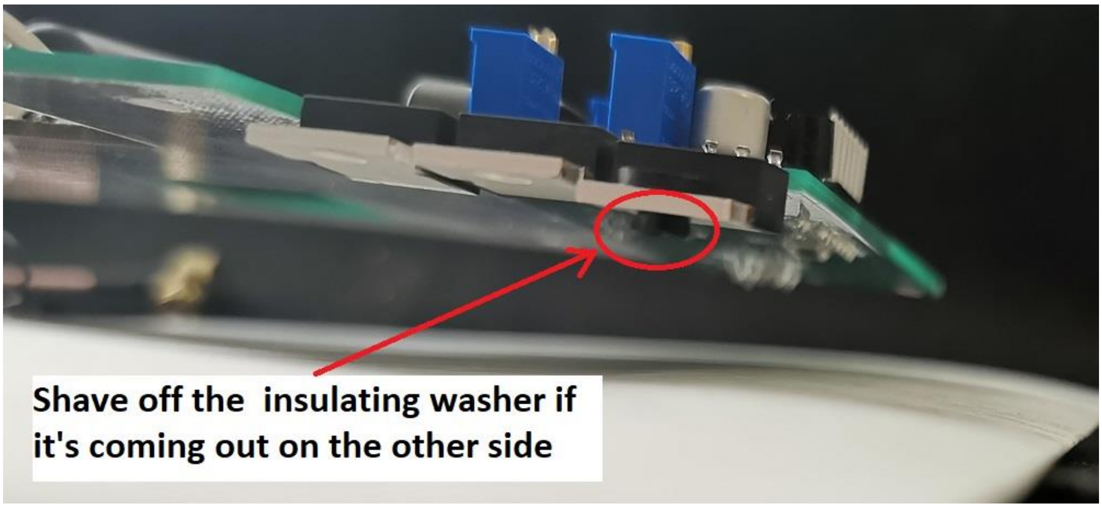


Solder the two power screw connectors in place; make sure you use enough solder, as there will be some mechanical stress when tightening down the connections.

With the PCB board temporarily bolted to the heatsink with the 4x M4 bolts, place U2 (LM317HVT) in its position and solder its legs; cut any excess length.

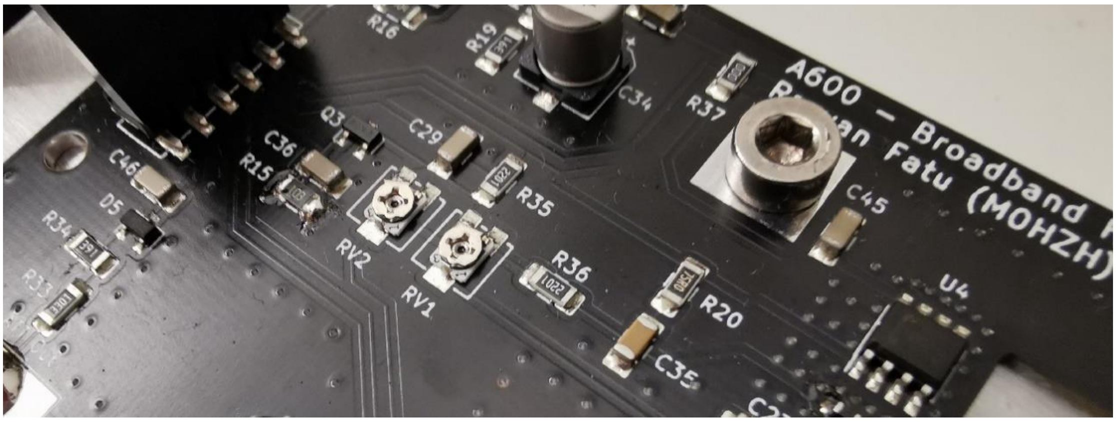
Remove the bolts holding down the PCB to prepare the assembly for permanent mounting. Clean the surfaces thoroughly (soapy water & sponge, wash with plenty of water, wipe with an alcohol-soaked cloth and leave to dry) and apply sufficient thermal grease on U2. You will need to use the insulating mounting kit (mica sheet and plastic washer). If the washer is too long and comes out on the other side of the IC tab, make sure to shave it off with the utility blade so it's level.

See picture below for reference (older version of the board):



Place PCB on the heatsink and screw down the four M4 bolts.

Before installing Q1 and Q2, rotate RV1 and RV2 completely anti-clockwise and with the board powered with +48V, check the voltage at the Gate pad of Q1 and Q2 is around 2.2V.



Measuring the voltage at the Gate pad for Q1, adjust RV1 until the voltage is around 2.2V and do the same for RV2 while measuring the Gate tab of Q2.

Remove +48V supply and install Q1 (MRF300AN) and Q2 (MRF300BN). Their legs would have to be cut short (see picture below for reference) to be able to fit. If you chose a liquid metal thermal interface, make sure you apply a thin layer on both the copper side and the back of the transistors. Tighten the bolts first and solder the legs afterwards, so there is minimal mechanical stress to the solder connections.

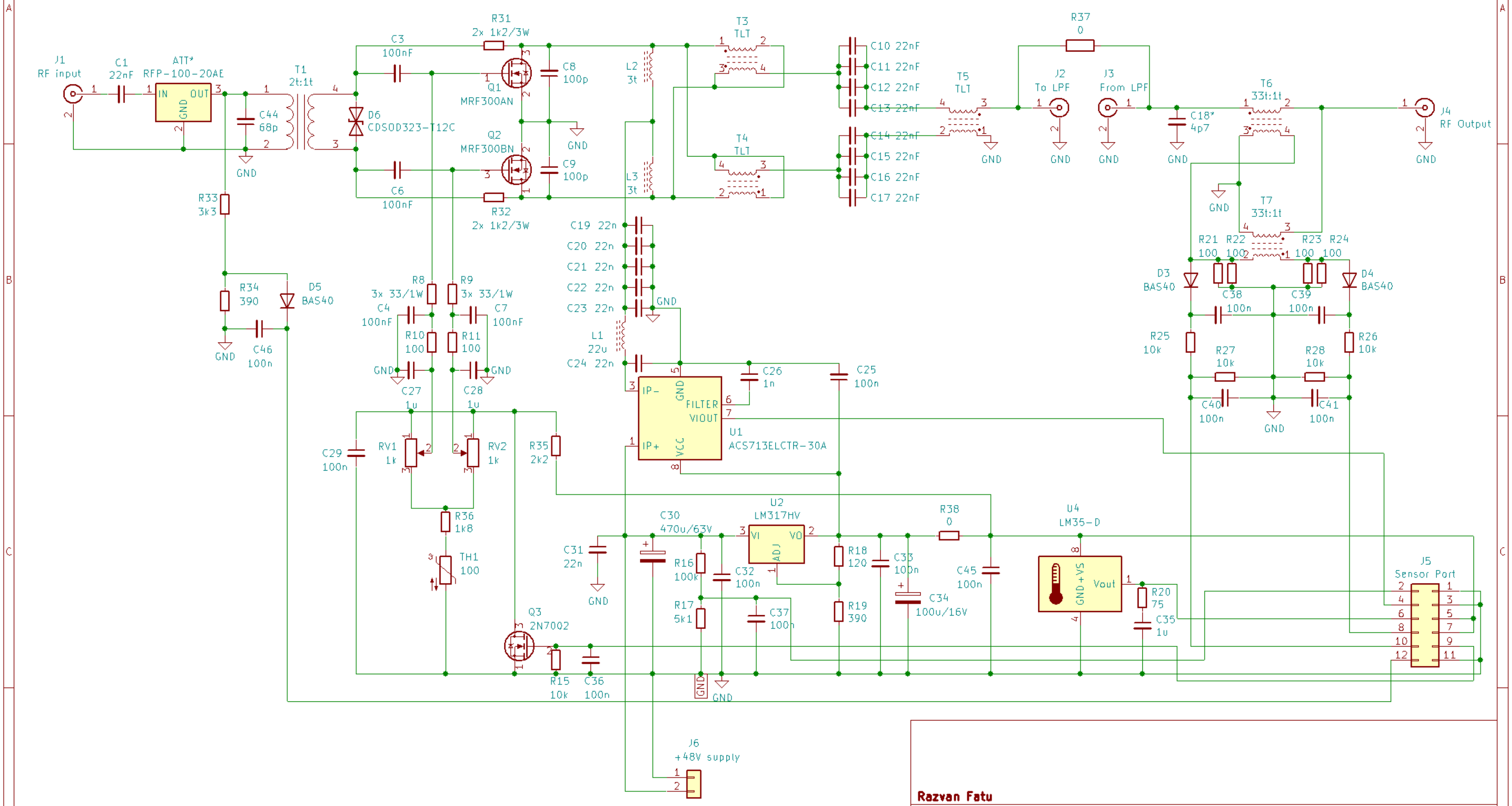
Once that's done you can install the last parts, the large 1200ohm / 3W resistors, as in the picture. Two paralleled resistors are used on each side to make up R31 and R32 respectively.

Setting idle current

Now you can apply +48V to the board again and monitor current drain with a multimeter, which should be around 60mA. Slowly turn RV1 so the Gate voltage increases until the total board current has increased by 200mA (for example to 260mA if the initial drain was 60mA). Do the same for RV2 until the current has increased by another 200mA.

From now on, you can test with RF drive, carefully measuring output power, drain current and heatsink temperature.

Never exceed 5-6W of drive to the amplifier as this will damage the power transistors.



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Title: A600 Broadband 600W linear amplifier with MRF300 transistors

Size: A4 | Date: 2020-02-02 | **Rev: 2.1**

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